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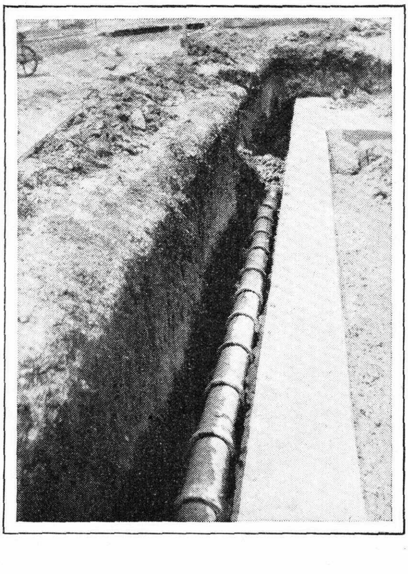
MAKING CELLARS DRY



MANY KNOW the annoyance and ill effects of wet basements and cellars, but comparatively few are familiar with good remedial methods. This bulletin gives needed information and supersedes Year Book Separate No. 824, "Securing a Dry Cellar."

Many wet cellars might be dry had a little more attention been given to their location and construction and to grading the earth around them to shed water quickly. Frequently wet cellars can be made dry by gravity drainage of the site—the simplest and surest method of avoiding ground-water troubles. Many damp cellars can easily be made less damp by better window ventilation. Water-tight construction and waterproofing and damp-proofing methods require good materials, but the most important thing—in fact the vital thing—is thorough workmanship in each and every detail.

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MAKING CELLARS DRY

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INTRODUCTION

A person who proposes to build, buy, or rent a house should consider the possibility of water and dampness in the cellar. Discovery of trouble after occupancy causes inconvenience and expense. Houses with wet cellars often stand idle for months and sometimes for years. Such cellars feel colder than dry cellars of the same temperature, and because of lack of windows and ventilation they are often dark and musty. Real estate dealers say that a good dry, light cellar adds $500 to $1,000 to the value of an ordinary dwelling. Moisture and darkness favor mildew, molds, decay, and putrefaction; moisture also hastens the corrosion of metals. Hence, a dry cellar makes for wholesome, sanitary conditions in the home; promotes personal comfort and health; lengthens the life of houses, furnishings, and plumbing; and increases the usefulness of basements for storage, workshop, and laundry purposes.

LOCATION

It is better to avoid mistakes than to correct the consequences. Where a choice is possible careful consideration should be given to the selection of the site for a new cellar. The following are important points to be observed:

(1) The site should be moderately elevated so that a fall in at least one direction is obtained. Many prefer a "perched" site because of commanding view, better movement of air, greater depth to the water in the ground, and superior surface and underground drainage. Others prefer to forego some of these advantages and select sites sheltered from strong winds, especially those likely to bring stormy or cold weather. Figure 1 shows a good site and two that are less favorable.

(2) The soil and subsoil should be open and porous so that air and water are admitted readily. Examples of such soils are sands, gravels, and loams.

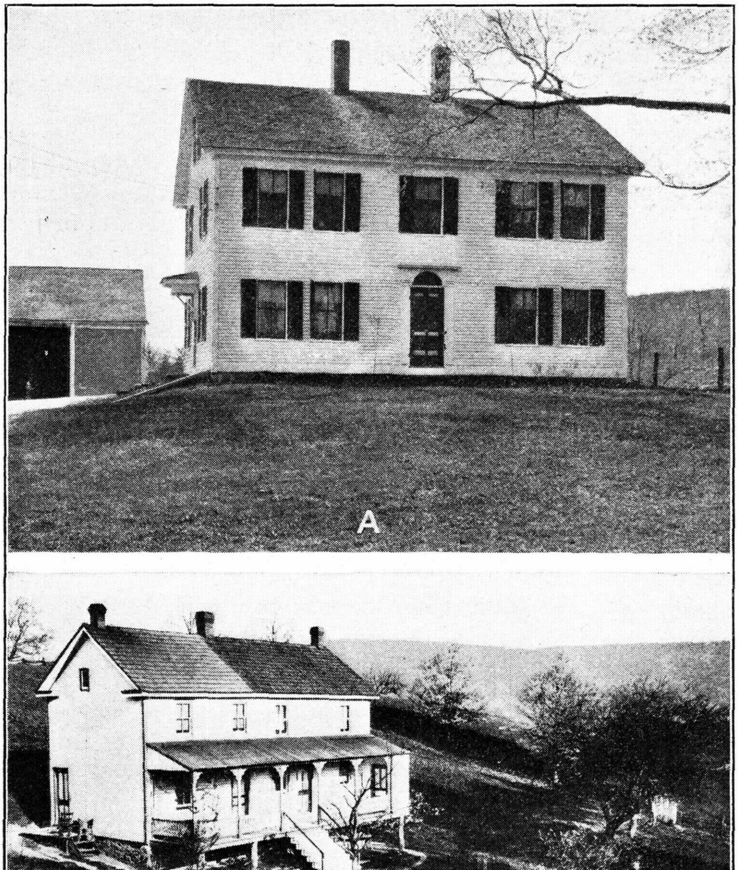

FIGURE 1.—Sites: A, Excellent; B, sidehill sites are subject to upland drainage; C, pond and flat ground indicate shallow drainage

(3) The site should have good, deep, natural drainage. During the wet season of the year the ground water should be at least 10 feet below the surface of the ground. A depth of 15 feet insures still better aeration and ventilation of the ground. As to the distance between the cellar botton and the ground water, much depends on the character of the intervening earth and the type of floor used. In the same way that oil rises in a lamp wick or ink penetrates blotting paper, water will pass into the minute spaces or pores existing in all kinds of soil and the softer varieties of rock. This absorption, or capillary rise, in coarse sands may not exceed 2 or 3 feet, but in very fine sands, silts, loams, and clays it may range from 5 to 8 feet. In lateral directions the movement may extend much farther.

(4) No site should be chosen until the source of the domestic water supply has been determined, its purity and abundance have been assured, and the location of a suitable plot of ground in which to waste sewage or other foul drainage has been fixed upon.

CAUSES OF DAMPNESS AND WETNESS

There are many causes of damp or wet cellars. Sometimes the trouble is slight, resulting from an apparent and easily remedied local cause. Sometimes the trouble is serious, resulting from hidden and not easily corrected causes. The cause or causes should always be studied and determined, so that the simplest effective treatment may be employed. The principal causes are as follows:

(1) Land which is flat or slopes toward the cellar wall, down and through which percolates rain and melting snow. The drainage may be over the surface or underground and usually results in damp spots, or standing water at cellar corners and along the junction of floor and walls, as shown in Figure 2, A. The conditions are usually worst in the spring of the year when the ground is very wet; in compact soil having poor natural drainage; on the upper side of side-hill cellars; and in poorly constructed cellars like those in Figure 2.

(2) Absence of eaves troughs and down spouts, or failure to repair defective ones, frequently resulting in surface depressions, muddy pools, bespattered walls, and water-soaked ground near or against the cellar wall.

(3) Ground water close to the cellar bottom through which water rises by capillarity, producing merely dampness.

(4) Ground water higher than the cellar bottom, causing standing water in the cellar and at times excessive dampness in the rooms above.

(5) Sweating or condensation of atmospheric moisture on walls, floors, and other cold surfaces within the cellar.

(6) Leaky plumbing; drip from ice chests and sill cocks; dense masses of vines, shrubbery, and trees.

In contrast to the poorly constructed cellars shown in Figure 2, attention is called to the appearance and usefulness of the good cellars shown in Figure 3.

ROOF WATER

Buildings having cellars generally should be provided with eaves troughs (gutters) and down spouts (conductors or leaders). A common type is shown in Figure 4, A. Troughs should be kept in

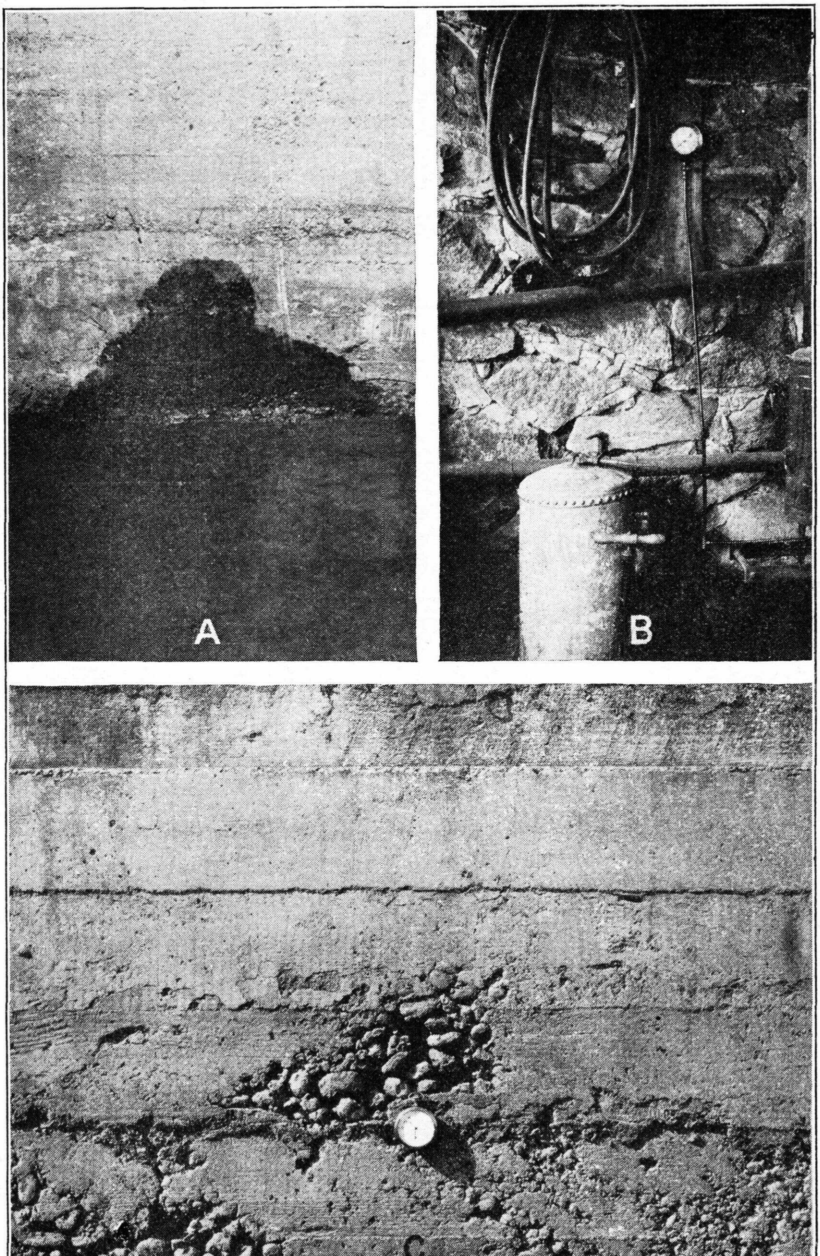

FIGURE 2.—Poor construction and water-tightness are incompatible: A, Water finds the weak spot at junction of floor and wall; B, rough rubble wall; C, poorly spaded honeycombed concrete wall

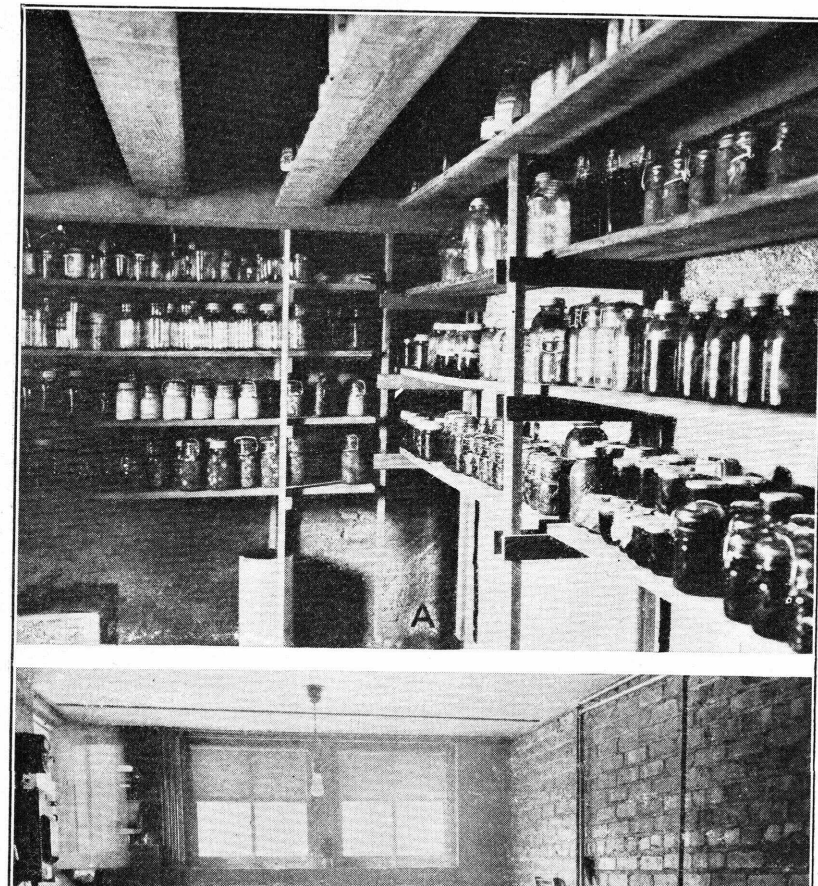

FIGURE 3.—A dry, light cellar is more useful than one that is damp and dark: A, Vegetable and fruit storage cellar; B, farmhouse basement, Illinois

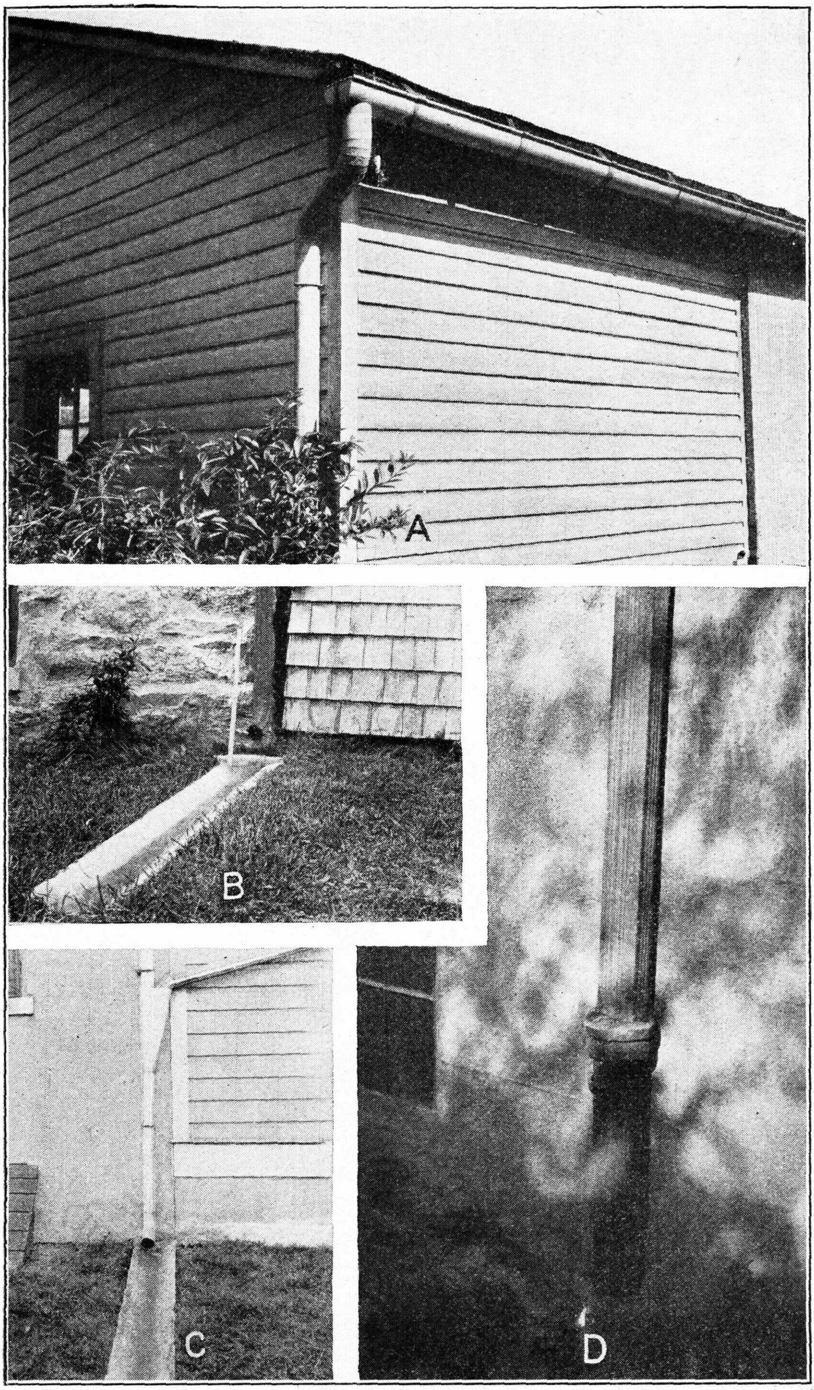

FIGURE 4.—How to lead roof water away from buildings: A, Half-round galvanized gutter, end piece, elbows, and plain round conductor; B, concrete gutter with upper end enlarged to catch all the discharge from the conductor shoe; C, concrete gutter 2 inches deep, 9 inches wide, and 10 feet long; D, square corrugated conductor cemented into a connection of ordinary 4-inch cast-iron soil pipe

good repair, well painted, and free from twigs, leaves, and other obstructions. Where the nearness of trees is likely to cause litter to collect in the trough, the trough outlet should have a basket-shaped wire strainer. Where the down spout from such a trough is so connected as to discharge underground as shown in Figure 4, D a strainer is especially useful in preventing obstruction in the drain.

Study of the intensity and frequency of rainfall in the United States indicates that there are few localities where provision need be made for removing more than 4 inches per hour from the roofs of farm buildings. Heavier rains may and do occur, but they are usually accompanied by strong wind which blows some of the water clear of the eaves troughs, and they are likely to come during those seasons of the year when a small spill from the roof does little harm. Table 1 shows suitable sizes of eaves troughs and down spouts for roofs of varying horizontal (ground plan) area. The figures in Table 1 are based on a 4-inch-per-hour rainfall and on commercial sizes of round down spouts and half-round eaves troughs sloping one-tenth inch per foot. Square, rectangular, or other shaped sections of equal area may be used.

TABLE 1.—*Sizes of half-round eaves troughs and round down spouts for various roof areas*

Area of roof (horizontal), (square feet)	Rainfall per minute, (gallons)	Eaves troughs (nominal size)	Down spouts (nominal diameter)
		Inches	*Inches*
100 or less	4 or less	3½	2
100 to 800	4 to 33	4	3
800 to 1,000	33 to 42	5	3
1,000 to 1,400	42 to 58	5	4
1,400 to 2,000	58 to 83	6	4

Spacing of down spouts varies with their size and with the area and type of roof. A plain gable roof (center ridge) 30 to 40 feet long would ordinarily require two 3-inch down spouts—one for each slope—placed at the same or opposite ends of the roof according to the slope and drainage of the grounds. A gable roof 60 feet long would ordinarily require four 3-inch down spouts, one at or near each corner. The eaves trough would slope up from each corner forming a summit or high point midway between down spouts. If it is necessary or desirable to slope them away from instead of towards the corners, two 4-inch down spouts about midway of the roof would be sufficient. Hip or pyramid roofs 30 feet square ordinarily require two 3-inch down spouts, one at or near either diagonal corner, summits being formed in the eaves troughs at the other two diagonal corners. Large hip or pyramid roofs usually have four down spouts, one at or near each corner.

A down spout usually has an elbow or shoe which discharges slightly above ground and away from the cellar wall. It is very important, especially where the ground is flat or drains poorly, to avoid concentration of water at any point. A simple and satisfactory way of leading the discharge away from the cellar wall is

shown in Figure 4, C. This is a homemade concrete gutter 2 inches deep, 9 inches wide, and 10 feet long, sloping about 1 inch per foot and with edges flush with the ground surface.

Sometimes **V**-shaped or **U**-shaped gutters of wood, brick, or stone, or a few lengths of half-round, vitrified gutter pipe are used. To catch all the discharge from a down spout the upper end of the gutter is frequently widened and shaped like a platter, as shown in Figure 4, B.

Wasting roof water on the surface has the advantage of permitting ready inspection and clearing of down spouts should they become obstructed. Frequently the discharge is piped underground to a suitable drain, abandoned well, dry well or surface outlet 15 or more feet from the building. About 2 feet above ground, as shown in Figure 4, D, the down spout is cemented into a piece of cast-iron pipe extending to a quarter-turn elbow set below frost depth. The line to the well or outlet is completed with ordinary draintile or sewer pipe with cemented joints. The bottom of a dry well should be lower than the cellar bottom and in earth or rock that drains rapidly. To facilitate the removal of obstructions in the elbow or drain, it is a good plan to set in the cast-iron riser a **Y** cleanout or branch with removable plug just above the ground surface.

SURFACE DRAINAGE

Many a cellar is wet because the surrounding ground is flat or slopes toward it. Such a cellar may be improved by grading the ground to form a smooth, sharp, downward slope extending at least 10 feet from the building, thus insuring quick shedding of surface water. Water in the ground moves much more rapidly downward than laterally. Hence, if surface water can be carried quickly away from a cellar wall, a large part of that which enters the ground will probably sink below the level of the cellar rather than spread laterally to it.

Setting dwellings too low is such a common mistake that the old adage, "decide on the grade of the sill and then set it a foot higher," is not far amiss. A fairly good rule is to make the top of the cellar wall at least 1 foot plus the height of the cellar window sash above the highest point of the finished grade or ground surface 10 feet from the building. For example: With level ground and a window sash 1 foot 3 inches high, the frame being set flush with the top of the cellar wall, the top would be 2 feet 3 inches above the ground. Although this allows a ½-inch-per-foot slope in the grading (average sidewalk slope) with the bottom of the window sill about 3 inches above the graded dirt, it is undoubtedly wise in many instances, especially where the ground water is high and the natural drainage is poor, to make the cellar bottom and wall a little higher and to steepen the grading as shown in Figure 5.

Where existing buildings are too low and it is necessary to grade as high as the cellar windows, a curved or rectangular wall of concrete, brick, or tile may be built about them as shown in Figure 6.

After the grading is completed it should be seeded with a good lawn grass, raked, and rolled. Handled in the manner described, a sharply sloping, well-sodded zone around a building does much to

carry off surface water, keep the cellar dry, and improve the appearance of a low-set building.

The space between cellar walls and the excavation is usually back filled with loose dirt and more or less waste material, such as pieces of stone, broken bricks, and bits of wood and mortar, the whole forming a porous medium for the easy passage of water to the wall. The space should be filled and compacted with clayey material or, if not too wide, with concrete. Where the filling has been poorly done, and in order to shed water quickly, a sloping pavement or gutter is sometimes laid as shown in the upper view of Figure 7. The pavement may be made of Portland-cement concrete or bituminous concrete and is usually 1 to 3 feet wide.

If it is necessary to conduct water along a cellar wall the pavement should be shaped like the gutter in Figure 7, B, and given a slight, smooth grade its whole length. A gutter 18 inches wide, 3 inches deep, and graded 1 in 100 is ample for the largest farm dwelling.

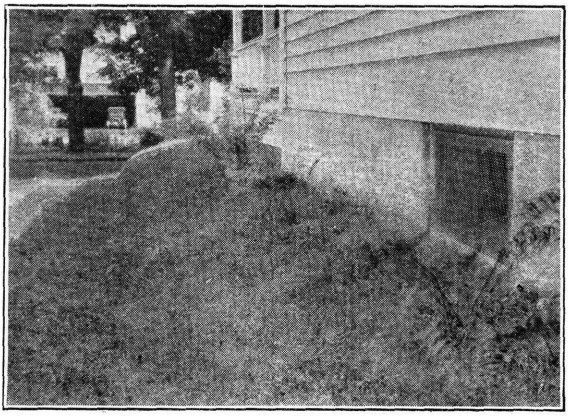

FIGURE 5.—Earth graded sharply to shed water from a cellar wall

Where a considerable area of land slopes toward a building it is advisable to intercept surface drainage at a distance from the cellar. This can usually be done by scooping out a small, half-round drainage ditch to run through any slight depressions along the contour of the land. If a ditch is objectionable, draintile, with one or more catch basins at low spots, may be laid.

GROUND WATER

The importance of deep thorough drainage of building sites can not be overestimated. Where seepage works or may work through a cellar wall or where the ground water is or may rise higher than a cellar floor, a drain should be constructed, provided a drainage outlet can be obtained within reasonable distance. Even where special waterproofing measures are employed it is a wise precaution to drain off the ground water as low as or lower than the bottom of cellar walls and the under side of cellar floors.

The usual practice is to lay a 4-inch tile drain, as shown in Figure 8, close to the bottom of the cellar wall or footing course on the side or sides from which water comes. About a foot extra width is excavated to give space for laying the drain. The bottom of the tile should be as low as the bottom of the wall or footing course but care must be used never to undermine it. The drain is usually laid with little slope because down spouts are not connected to it and

hence it carries comparatively little water. Both the line and slope of the drain should be straight and smooth. Good concrete pipe, well-burned draintile, or ordinary sewer pipe may be used. The joints should be kept open about the thickness of a knife blade, and to prevent entrance of loose dirt a strip of burlap, linen, or other porous fabric 6 inches wide and about 17 inches long should be tied or wired around each joint. The trench should then be refilled with screened gravel, broken stone, cinders, or other coarse material up to within a foot of the surface of the finished grading. It is desirable to use gravel or stone from 1/4 to 1 inch in size, placing some of the finer around and over the pipe to give good bedding and protection.

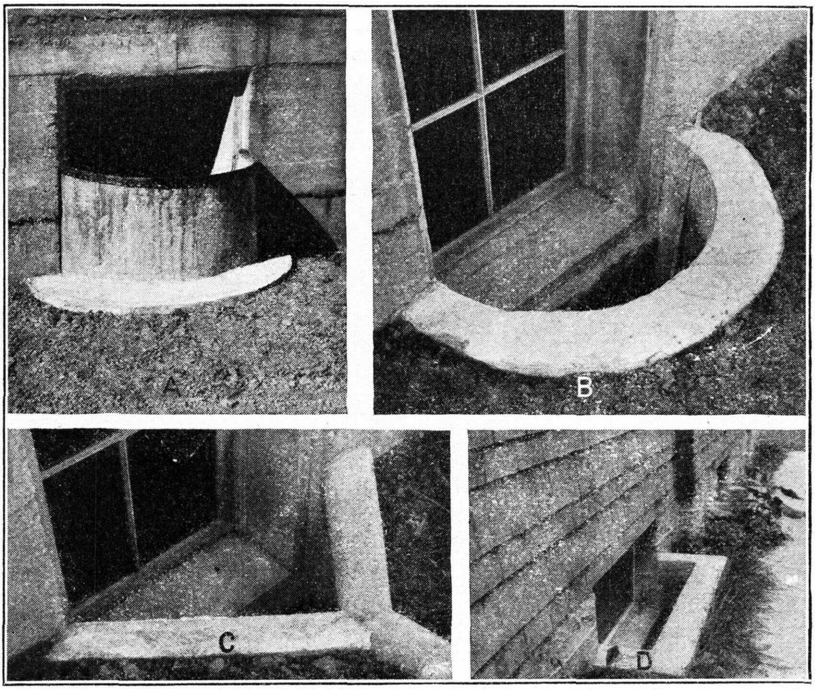

FIGURE 6.—Shallow concrete walls to restrain grading around cellar windows: A, Steel form used to shape a half-round concrete wall; B, completed well 20 inches deep; C, V-shaped well; D, shallow rectangular well

To prevent loose dirt washing down into the stone or cinders, the top should be covered with old bagging, burlap, hay, straw, cornstalks, sods with grass side down, or fine brush. On this mat about a foot of topsoil is placed, graded, and seeded as previously described.

A drain and belt of coarse material thus placed around a cellar wall not only collects and carries off seepage water but is effective in intercepting dampness. The method is especially suitable on the upper side of hillside locations because a drainage outlet can usually be obtained within a short distance. If necessary to drain deeper than the foundation the drain may be placed 4 or 5 feet away to avoid undermining it. It is sometimes desirable to lay one or two branch drains to tap springs within a cellar.

CELLAR DRAINERS

Where gravity drainage is impossible or impracticable, cellar drainers or pumps are often employed to raise the water to the surface, whence it runs away through a gutter or pipe. These appliances are small, simple, and compact and are installed in a pit 1½ to 2½ feet deep at the low corner or other wet spot in the cellar. To admit ground water and to prevent caving of the sides, the pit is curbed with a length of large draintile or sewer pipe, with concrete, brick, or stone, or with a keg or strong barrel having a few ½-inch holes in its side and bottom. Drainers of the ejector type are operated by water or steam under pressure, the high velocity of a small jet entraining the pit water and lifting it, together with the jet water, from the cellar. Pump drainers are usually operated by small electric motors. Both types of drainer are shown in Figure 9.

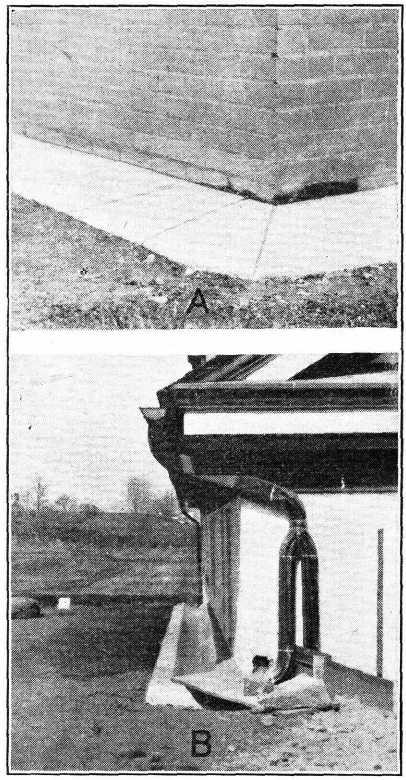

FIGURE 7.—Sloping concrete pavements about 18 inches wide: A, Shedding water from a cellar wall; B, conducting water along a cellar wall

Drainage usually reaches the pit slowly and intermittently, depending on soil conditions and rainfall, and drainers are equipped with a float valve to make their operation automatic. If correctly installed and not abused, drainers require very little attention. Dirt, trash, laundry lint, or other wastes, which may clog the strainer should be kept out of the pit.

CELLAR CONSTRUCTION

Good cellar construction lessens the liability to future trouble. The following suggestions will prove helpful.

(1) The cellar wall should be started on a firm, dry, level bottom or on a substantial concrete footing course at sufficient depth to give a clear height of not less than 6½ feet from the finished cellar floor to the bottom of the main beam supporting the first-story floor joists. Although a deep cellar may be damper than a shallow one, it is well to note that uniformity of temperature tends to increase with depth. The temperature of natural ground at 5-foot depth is rarely more than 15° above or 15° below the mean annual air temperature of the locality; at 10-foot depth the corresponding range is rarely more than 10° above or 10° below the mean. Old-time New England milk cellars, sometimes 15 or more feet in depth, have notably cool, even temperatures.

(2) Availability and cost usually determine the wall material. Stone, brick, concrete, solid or hollow concrete blocks, and very strong, dense, vitrified, hollow clay tile are in common use. Plastering the outside of stone, brick, or other jointed masonry walls with a ½-inch coat of 1:1½ Portland-cement mortar is a great aid in shedding water down the wall and keeping it out of the joints.

(3) For one and two story dwellings and similar structures the cellar walls should not be thinner than 16 inches for rubblestone, 12 inches for brick, solid or hollow concrete blocks, or clay tile, and 8 inches for solid concrete.

(4) Ample windows should be provided for light and ventilation. Although a well-lighted living room has about 1 square foot of unobstructed glass per 100 cubic feet of room space, the results are generally satisfactory for ordinary cellar purposes if there is 1 square foot of unobstructed glass per 300 to 400 cubic feet of cellar space. There are, of course, many factors, such as intensity of the light, reflection from adjacent buildings, direction of exposure, size of cellar, presence or absence of partitions, and color of partitions, walls, and floor, which strongly influence cellar lighting. The preferable location of windows is one on each side to allow illumination of opposite walls and free movement of air (ventilation) across the cellar. Clean, smooth, whitewashed, or Portland-cement grout painted walls greatly improve the lighting effect.

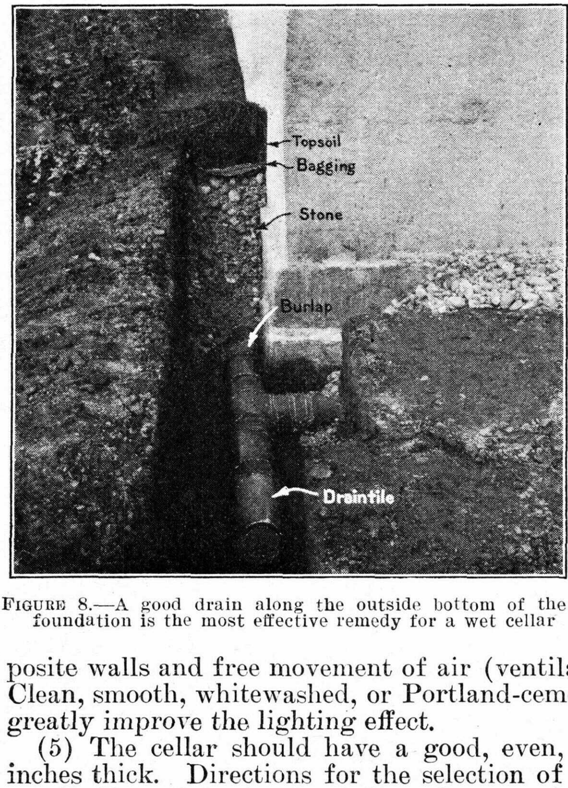

FIGURE 8.—A good drain along the outside bottom of the foundation is the most effective remedy for a wet cellar

(5) The cellar should have a good, even, concrete floor about 4 inches thick. Directions for the selection of materials and the proportioning, mixing, and placing of concrete in floors and walls are given in Farmers' Bulletin 1772, Use of Concrete on the Farm. The floor should be given a slight slope in one or two general directions

to aid in the removal of water should it chance to enter. A trapped floor drain is sometimes employed for this purpose and is useful when draining washing machines and heaters and scrubbing floors. If a floor drain is installed, the floor should slope slightly from all directions toward it. Generally a floor drain is used infrequently, and the water in the trap evaporates, allowing drain air to enter the cellar. Therefore the installation of such a drain is not recommended unless there is frequent need for it.

(6) There should be a good ceiling of plaster on laths (preferably metal lath), plaster board, or other suitable insulation.

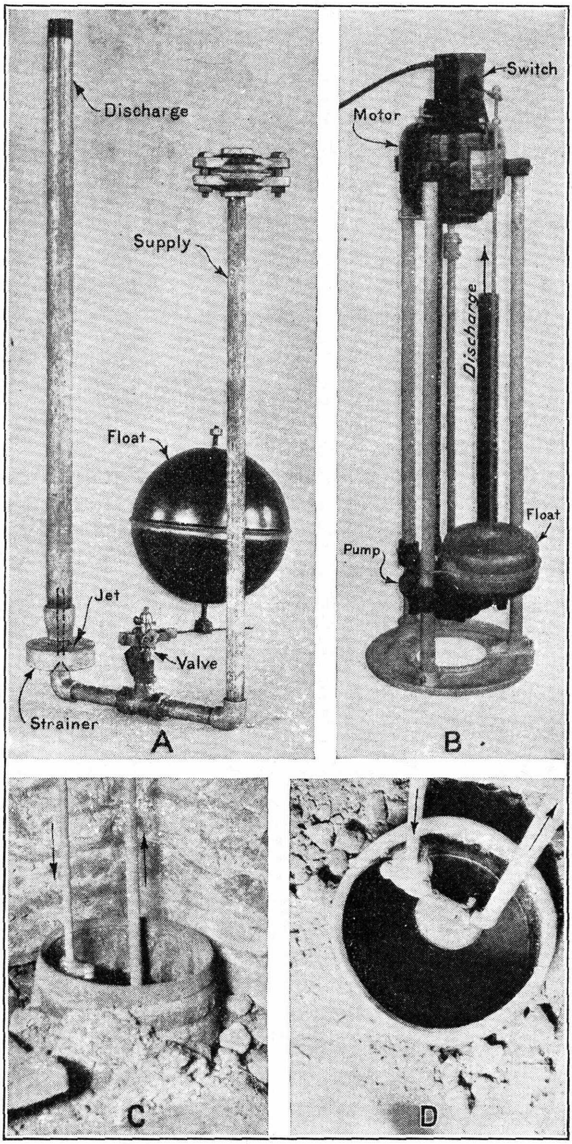

FIGURE 9.—Automatic cellar drainers: A, Main parts of a float-controlled hydraulic drainer; B, main parts of a float-controlled electric drainer; C, wooden barrel containing a hydraulic drainer in use 18 years, Maryland; D, looking into barrel from above; drainer cost approximately $12; including pipe and labor the installation cost $25

WATER-TIGHT CONSTRUCTION

Where a cellar floor is below the ground-water level and the water can not be lowered by drainage, water-tight construction is required. Concrete is generally preferred, and one of the following two methods of waterproofing is commonly employed.

(1) Integral method, or dependence on close, compact construction of the wall itself.

(2) Membrane method, or use of a specially prepared felt, cotton drilling, or other approved fabric put down in overlapping layers,

coated and cemented together with hot coal-tar pitch or asphalt, the whole forming, or intended to form, a virtually water-tight box in which the main walls and floor are placed.

INTEGRAL METHOD

A considerable number of farmers do concrete work that is water-tight. Asked their secret, they are likely to say they "put in a little extra cement." Although richness of mix is important it is only a small part of the story. In addition, water-tight concrete requires good sand and stone and first-class workmanship in mixing, placing, and curing the product. Furthermore, the best concrete may avail little if leakage occurs at construction joints, at seams between successive layers or successive days' work or at cracks caused by settlement, shrinkage, or expansion. It is well known that concrete contracts slightly with drying or cold and expands slightly with wetting or heat.

Water-tight concrete is briefly treated in Farmers' Bulletin 1772 referred to on page 12. Additional suggestions for obtaining the desired results are as follows:

(1) The work should be done in mild, dry weather, preferably in the fall because the ground water is likely to be low and air temperatures, approximating 50° to 60° F., are favorable to the making of water-tight concrete. Where newly placed concrete would be subjected to water under pressure the water should be removed by pumping or bailing. A spring beneath a floor or seepage against a wall can seldom be smothered with fresh concrete.

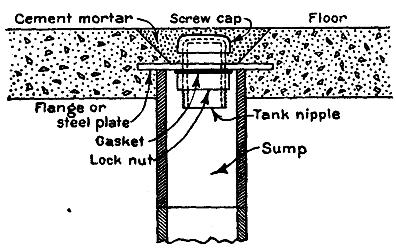

FIGURE 10.—Pump hole in a concrete floor

(2) Where a pump hole or sump must be floored over it should be constructed of one or two lengths of 6-inch draintile with a large flange or steel plate screwed to a tank nipple and embedded in the concrete as shown in Figure 10. The nipple should be sufficiently large to pass the suction pipe into the sump. When the floor is completed and pumping is discontinued, the top of the nipple is tightly closed with a screw cap, and the hole is filled with cement mortar, or concrete.

(3) Concrete should be mixed long and thoroughly, fresh Portland cement, clean coarse sand, clean sound stone not exceeding three-fourths inch in diameter, and the smallest quantity of water that will give a plastic, sticky, smooth-working mixture being employed.

(4) Concrete should be placed in as nearly a continuous operation as possible to lessen the number of construction joints and seams. The concrete should be spaded no more than is necessary to avoid a honeycombed condition. (See fig. 2.) Too much working brings the cement to the surface and injures the uniformity of the concrete. If work must stop before a wall has been built above high-water level a continuous groove or keyway should be formed along the

top center of the last layer by pressing beveled 3 by 3 inch scantling, narrow side down, into the fresh concrete.

(5) Thorough protection and curing of newly placed concrete are vital to water-tightness. Immediately after placing, it should be protected from freezing or rapid drying by sun or wind, all of which injure concrete and may make it worthless. As soon as the concrete is sufficiently hard, so that the cement will not wash away, it should be drenched and kept continuously and thoroughly wet for two weeks. An occasional sprinkling is insufficient. Curing by complete submergence is very desirable. Although walls can seldom be treated in this way in most instances it is feasible to pond the whole floor. Walls are more conveniently cured by covering them with bagging, hay, or straw weighted down and kept thoroughly wet.

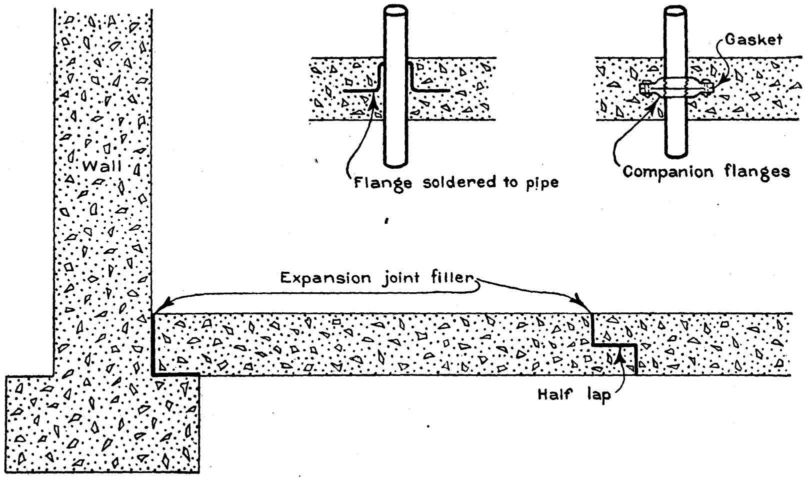

FIGURE 11.—Water-tight construction: Floor laid with expansion joints and in alternate squares not exceeding 10 feet on a side; pipes through floor or wall provided with tight flanges of a diameter two or three times the external diameter of the pipe

(6) Where there is considerable water pressure or wide variation of cellar temperature, the need for steel reinforcement should be considered. If the ground water never rises more than a foot above the under side of a concrete floor 5 inches thick, steel reinforcement may not be necessary, as such a floor has sufficient weight to resist the upward pressure of the water. If such a cellar is heated in winter and is kept reasonably cool in summer, the temperature range of the ground under the floor seldom exceeds 20°, and visible cracks rarely form, provided the concrete work is first class and especially if it has been cured under water. It is safer, however, to provide for expansion and contraction by some one of the following methods, and this should always be done where the temperature may range from near the freezing point in winter to 70° or 80° F. in summer.

The usual method is to lay the floor in alternate squares not exceeding 10 feet on a side. Just before laying the intervening squares, a brush priming coat followed by a heavy coat of hot asphalt or hot coal-tar pitch spread with a mop is applied to the clean dry edges of the squares and any abutting wall. Half-lap joints, shown in

Figure 11, further contribute to water-tightness. Expansion joints are also made with manufactured cushion strips of fiber matrix and bitumen the full depth of the joint, or by the use of a collapsible form, or a strip of smooth, well-greased board, to create a thin open joint which is afterwards filled with hot bituminous compound or mastic. A mixture of three parts of dry clay and one part of melted paraffin has also been used for joint filling. All pipes through the floor should be fitted with tight flanges or collars to be embedded in the concrete, as shown in Figure 11. Even an ordinary screw coupling is of value in preventing water from following along the outside of a pipe.

Sometimes, instead of laying the floor in squares, an unbroken reinforced concrete slab is laid, as illustrated in Figure 12. After the footing course and any necessary post foundations are laid, the floor is constructed with a 3 by 3 inch beveled keyway along the center

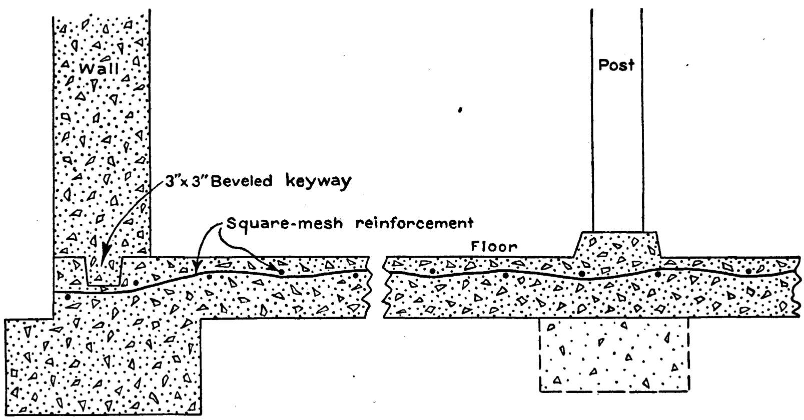

FIGURE 12.—Water-tight construction: Reinforced concrete floor with beveled keyway interlocking wall and floor

line of the wall, as shown in Figure 12 and as explained on page 14. Thus a tongue-and-groove effect is obtained which insures water-tightness between floor and wall, ordinarily the weak place. The reinforcement should be not less than ¼-inch round bars spaced 15 inches apart each way, requiring about 27 pounds of steel for 100 square feet of floor.

Standard wire-mesh reinforcement or expanded metal may be used instead of bars. A standard electrically welded square-mesh fabric composed of No. 8 gage wire spaced 6 inches apart each way approximates 30 pounds per 100 square feet and can be obtained in rolls of different lengths and widths as desired. A smooth, even 3½ or 4 inch base course should be laid in strips slightly wider than the roll, and the wire fabric, with all bulges hammered flat, should immediately be rolled upon and slightly pressed into the fresh concrete. The several strips of fabric are usually lapped about one mesh; an end lap, if needed, should also be one mesh. The top course of concrete should be promptly placed in the usual manner.

A 5-inch floor, stiffened as above described and carrying ordinary wall and column loads at intervals of 10 to 12 feet, is safe against

uplift where the ground-water level or head is 16 to 18 inches above the under side of the floor. For larger spans or higher heads the floor may need to be thicker and the steel heavier. Such construction should be designed and built to meet the requirements of each case.

MEMBRANE METHOD

The membrane method of waterproofing and damp-proofing concrete, brick, tile, or stone work consists of laying overlapping layers of a prepared waterproofing fabric and thoroughly coating and bonding every lap with hot asphalt or hot coal-tar pitch. The masonry itself may be leaky, but water-tightness is obtained by the coated fabric or membrane, which is laid through and around the masonry and virtually constitutes a turned-up mat or box outside of the main walls and floor. The method is reliable when the work is done by experienced men, and the ordinary individual by closely following instructions can do a reasonably good job. Where it is impossible to secure local labor experienced in cutting and applying membrane waterproofing, sketches, specifications, and explicit directions should be obtained from a reliable manufacturer whose materials are to be used. It is advisable to experiment with the materials on a small upright surface before attempting the actual work. The method is not cheap, and if leaks do develop they may be difficult to locate and costly to repair.

The materials and principal tools for home work are shown in Figure 13. The fabric generally used is a wool-and-cotton rag felt impregnated with asphaltic or coal-tar pitch saturating ingredients. The felt should be free of holes, rents, cracks, indentations, or ragged edges. Asphalt and coal-tar pitch in solid form are shipped in wooden barrels or steel drums. The compound as received from the manufacturer should be cut into small lumps with an ax and heated to about 300° F. in a kettle out of doors. Care should be used to avoid overheating which may make it brittle when cold and destroy its cementing properties. When the compound is fully melted and of uniform consistency it is an even glossy black. It should always be used when in this hot liquid condition and the mopping should be done rapidly.

The surface to which the felt is to be applied should be smooth, dry, and clean. Warm weather greatly favors the work. Brickwork should have struck joints, and holes and depressions in concrete or other masonry should be filled with Portland-cement mortar. Projecting stones or bits of mortar that might puncture the felt should be knocked off, and very sharp edges should be slightly rounded.

Figure 14 shows the membrane method as generally applied in new construction. After the footing course is placed and the bottom of the excavation is compacted and smoothed a 1-inch underbed of cement mortar or, if the conditions are severe, a thin underbed of concrete should be evenly spread over the whole area to form a base upon which to lay the floor membrane. A 4-inch brick or concrete wall should then be built to such height as the conditions require to form a backing for the wall membrane. The floor and wall membrane should be laid as a unit. Each strip of felt, lapped and coated with the hot compound, should be laid across the floor and be continued

without break at the wall angle up the inner face of the 4-inch veneer wall. After completion of the membrane a ¾-inch protecting layer of cement mortar should be spread over the whole floor area, and this should be covered with a 4 or 5 inch concrete floor recessed along the edge to lap and bond with the side wall, as shown. The main wall should be built close to or against the membrane, and all space be-

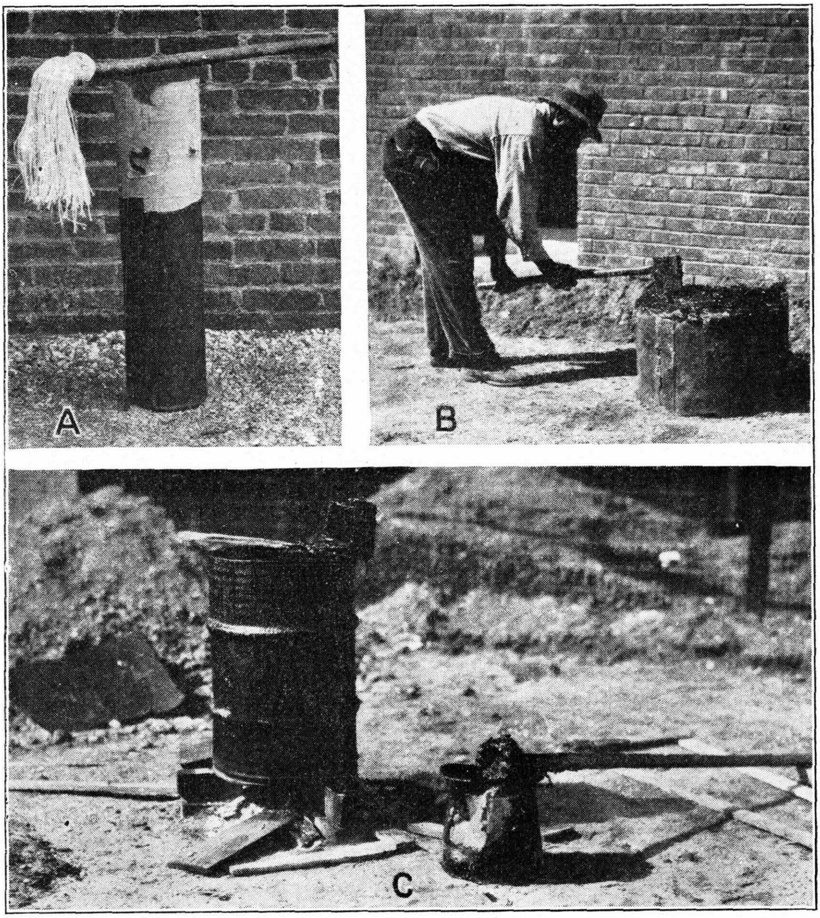

FIGURE 13.—Materials and tools for membrane waterproofing: A, Roll of felt and homemade cord mop; B, cutting the compound into small lumps; C, heating kettle consisting of an old 42-gallon gasoline drum set 6 inches from the ground on bricks and fired with wood

tween the wall and the membrane should be solidly filled, by pouring, with the hot compound or with Portland-cement grout.

Where it is not possible to waterproof the floor and wall in one operation especial care is necessary so that later the strips of felt may be properly interlapped and interlocked. Usually, if the walls are constructed first, a 12-inch strip of the cement underbed is laid along the footing course, and the wall membrane is brought down and over the footing course and underbed leaving a 6 to 12 inch

length of each strip of felt lying flat, and uncoated with compound, on the underbed. When the floor membrane is laid the uncoated laps are turned up, coated with hot compound, and interlocked with the floor sheets. Pending the main floor work, the membrane already placed, including the dry laps, should be covered with a waster sheet of dry felt and a thin protective coat of lean cement mortar. This covering is temporary and is removed when the floor membrane is laid, its purpose being to prevent injury to the felt by wheelbarrows, tools, or careless workmen.

The number of layers of felt which may be needed vary with the drainage conditions and the ends to be attained. Two layers of felt are generally sufficient where there is little or no head and the main purpose is to damp-proof. From three to five layers, depending on the height of the ground water are advisable for real waterproofing jobs.

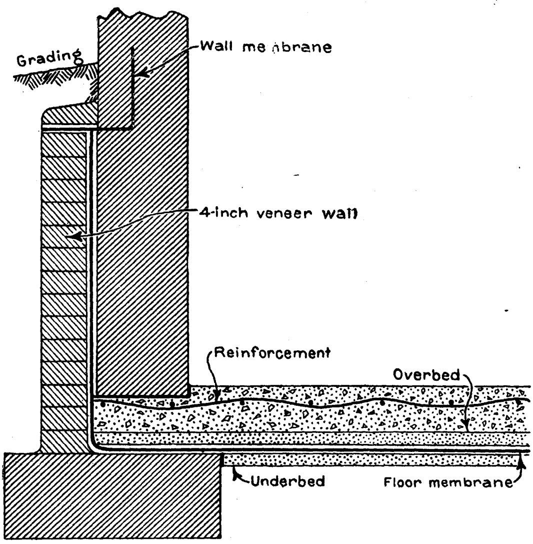

FIGURE 14.—Recommended application of membrane waterproofing

Figure 15 shows how the felt may be run and lapped in two-layer and three-layer work. End laps should overlap at least 6 inches. Each and every lap should be fully and evenly mopped with the hot compound, and the felt, closely following the mop, should be unrolled into the hot coating. This process, a strip at a time, is continued until every part of the surface to be treated has the required number of layers thoroughly cemented together.

With the intention of avoiding any seepage seam between the felt and the masonry, the two are sometimes united and bonded as effectively as possible, and in ordinary cellar work this is probably the better practice. For this purpose the masonry should first be given a suitable penetrating priming or bonding brush coat, applied cold, of about 1 gallon per 100 square feet. The use of a large, flat-bristle brush or a three-knot roof brush with long handle expedites the work. Without the priming coat the hot compound is unlikely to stick strongly to the masonry because of quick chilling and slight penetration, and the bond will be especially poor if the masonry is damp or cold. As soon as the priming coat sets, the surface should be mopped with hot compound, the felt being rolled into it as previously described.

The felt should lie perfectly smooth. Wrinkles and buckles should be smoothed out, and the sheets should be carefully pressed down

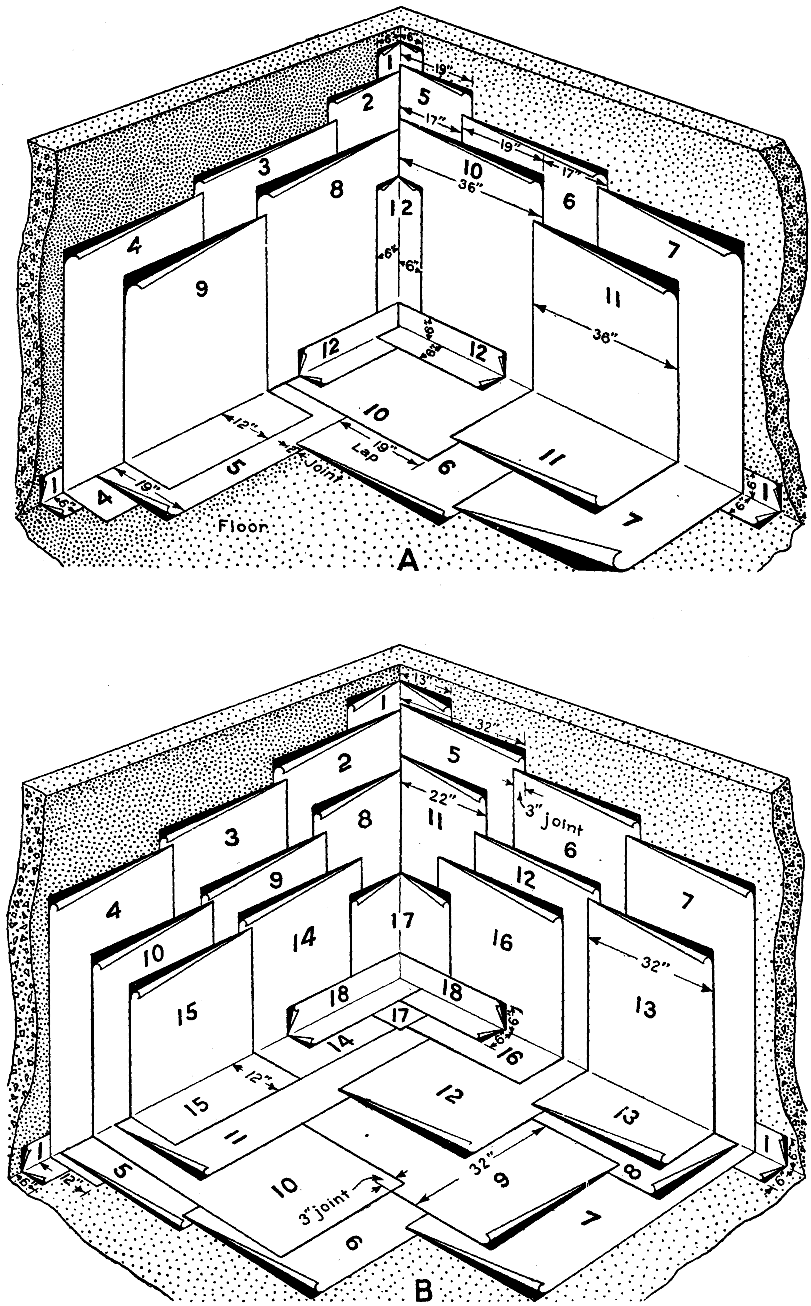

FIGURE 15.—Membrane waterproofing: A, Two layers of 36-inch felt, spaced 17 inches, overlapped 19 inches, jointed 2 inches; numbers show order of applying sheets. B, three layers of 32-inch felt, jointed 3 inches; intermediate floor layer crosswise of bottom and upper layers; wall sheets overlapped 22 inches, spaced 10 inches

and rubbed with the hand to remove air bubbles and to insure perfect bond between felt and felt. Special care is required to make the felt fit corners and angles neatly and snugly. To reinforce such places two strips of felt, cut to extend at least 6 inches each way from the angle, may be applied one strip before and one strip after placing the main waterproofing. After the several layers of felt have been cemented together the entire surface should be given a heavy mop coat of the hot compound. Five gallons per 100 square feet gives a top coating approximately five sixty-fourths inch thick. Each coat between layers of felt takes about 3 gallons per 100 square feet, and the mop coat over the primer on the masonry takes about 6 gallons per 100 square feet, making a total of 17 gallons of compound per 100 square feet for three-layer work and 14 gallons for two-layer work.

Thus there is built up a water-tight, more or less pliable, yielding blanket or membrane approximately one-third inch thick in three-layer work and one-fourth inch thick in two-layer work. Figures 16 and 17 show waterproofing work in progress, the views being arranged in the order in which the work is usually prosecuted.

PLASTER COATS

PORTLAND-CEMENT MORTAR

Plaster coats of Portland-cement mortar have been much used to waterproof and damp-proof cellars. Sometimes the results have been successful and sometimes disappointing. Much that has been said regarding the mixing, bonding, placing, and curing of concrete is equally true of mortar. Many failures with cement plaster are due to the sand being too fine or too coarse, too much water in the mix, plastering against seepage, poor preparation of the old surface, or poor bond between successive coats. Patches sag or slough off while the mortar is soft or scale off when it is hard. In other instances contraction cracks form, but this tendency may be partially offset by long wet curing of the plaster. Success is more likely to be obtained by employing skilled plasterers working in practically continuous operation so as to lessen the amount of joint work.

The surface to be plastered should be rough, thoroughly clean, and moist but not dripping. It should be kept wet by drenching with clean water for several hours prior to the application of the plaster. A dry surface will absorb moisture from the plaster and so prevent its proper setting and bonding. Just before the plaster is applied the moist surface should be given a brush coat of neat Portland-cement grout. Each plaster coat should be applied before the coat beneath sets hard so that all will knit or bond together. Each under coat should be lightly scratched or scored with a saw-tooth paddle, piece of metal lath, or sharp stick, checkerboardlike, thus improving the mechanical bond with the next coat. All coats except the last on the outside of walls should be well worked with a wooden float to make the surface slightly granular. A steel trowel should be used on an outside finish coat because it produces a smooth impervious surface, but overworking should be avoided as it creates a rich surface skin liable to crack badly and scale off.

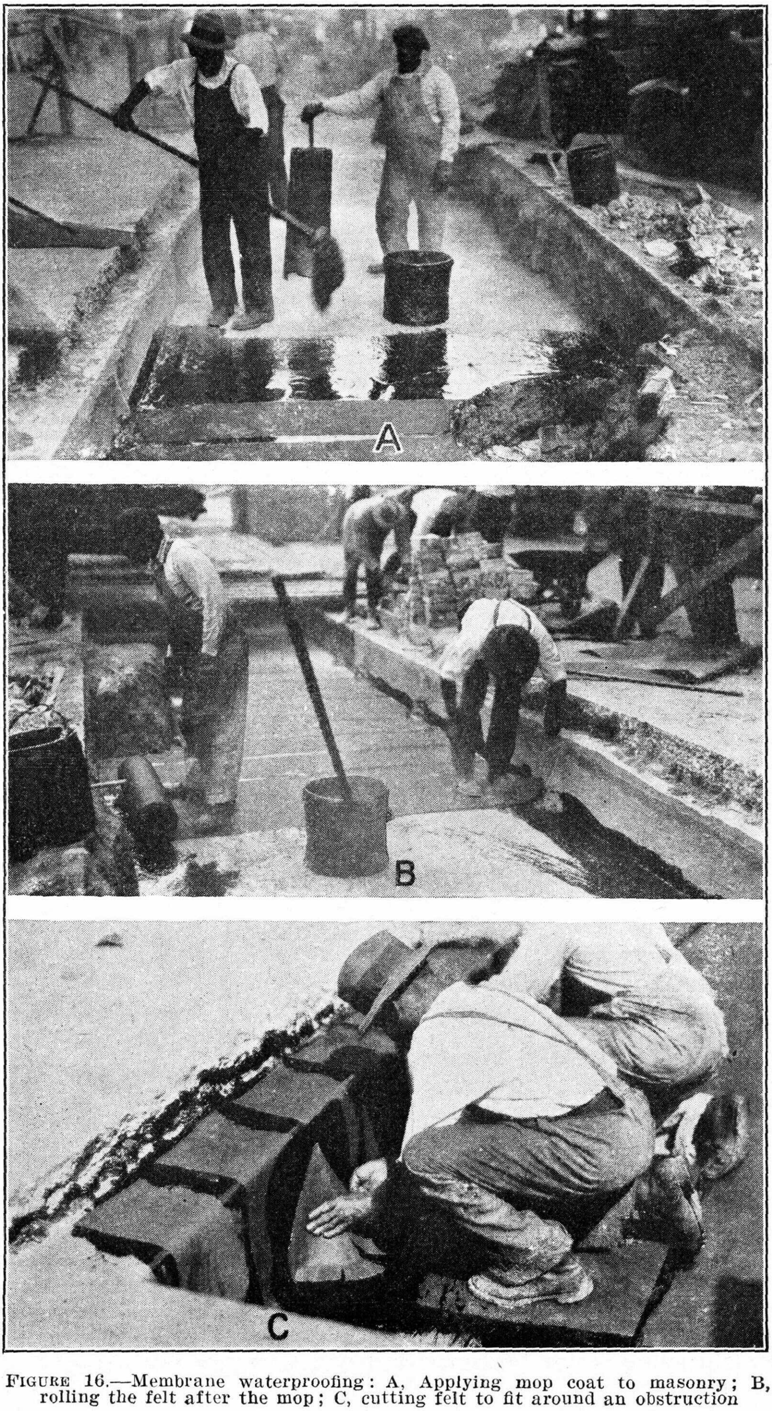

FIGURE 16.—Membrane waterproofing: A, Applying mop coat to masonry; B, rolling the felt after the mop; C, cutting felt to fit around an obstruction

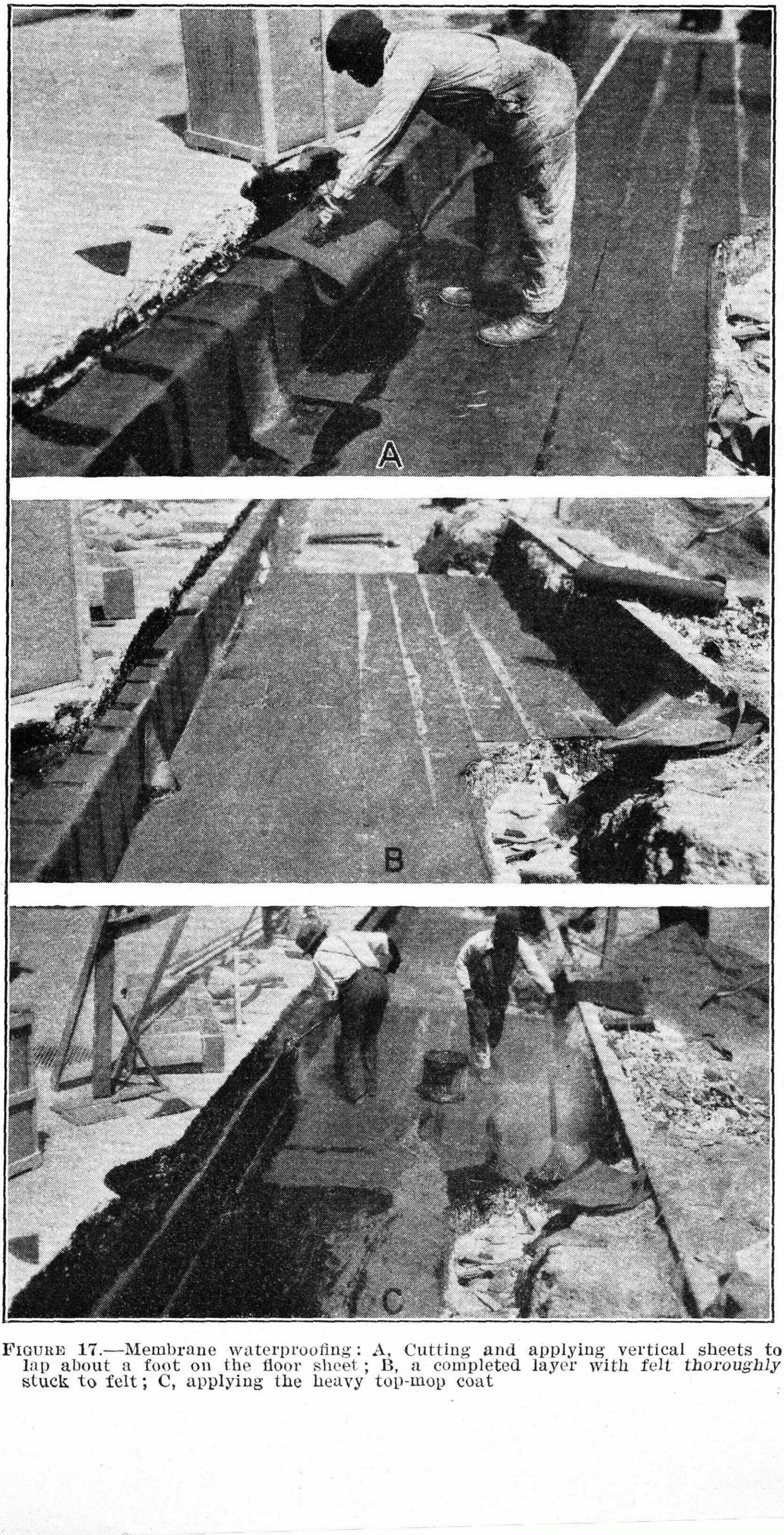

FIGURE 17.—Membrane waterproofing: A, Cutting and applying vertical sheets to lap about a foot on the floor sheet; B, a completed layer with *felt thoroughly* stuck to felt; C, applying the heavy top-mop coat

Floor plaster is usually applied in one coat about three-fourths inch thick. Wall plaster is applied in two or more coats each about three-eighths inch thick. A slight saving can generally be effected by making wall plaster a little thinner at the top than at the bottom. Damp-proofing plasterwork generally approximates three-fourths inch in thickness. Waterproofing plasterwork on the inside of walls generally tapers from 1½ to 2 inches in thickness at the bottom to three-fourths inch at the top. Waterproofing plasterwork on a floor liable to pressure from beneath should be underlaid with a properly reinforced layer of concrete from 2 to 4 inches thick, as described on pages 15 to 17.

Joints, angles, and corners are the weak places. There should be as few joints as possible, and they should be made on the wall or on the floor a foot or more from angle or corner. All angles and corners should be coved or rounded as a continuous part of the plastering. If the floor is to be plastered first and the walls must wait, the plastering should be carried up the walls about a foot, leaving a rough beveled edge which is later wet, brush coated with grout, and bonded with the wall plaster. Wall plastering should be started by making a rough vertical beveled edge on the flat surface, as it is difficult to make a tight closure at a corner. The plastering should be completed with as few vertical joints as possible. If the walls are done first, the plastering should be carried out on the floor about a foot, leaving a rough beveled edge to be grouted and bonded with the floor plaster. The latter method (walls first) is usually more convenient, but the first method (floor first) is more likely to give a water-tight job because the joint work is at a higher level. Plastering dries quickly and may crack. Just as soon as it is sufficiently hard, so that the cement will not be washed away, it should be drenched and kept continuously wet or flooded for at least a week.

BITUMINOUS-PLASTER COATS

Commercial bituminous mortars applied cold with a plasterer's trowel are used to damp-proof and to intercept shallow seepage. These plastic cements are usually asphalt or other bituminous material combined with asbestos fiber, mineral filler, and suitable volatile solvents. It is advisable before using such products to obtain explicit directions and specifications from the dealer or manufacturer.

The cement, ready for use, comes in containers holding from 30 to 500 or more pounds. It should spread smoothly and evenly, without drawing or pulling. A ⅛-inch coat requiring approximately 80 pounds for 100 square feet is usually applied to the outside of cellar walls and a ¼-inch coat to cellar floors. The wall excavation may be refilled after the plaster has dried 24 to 48 hours, care being taken not to injure it. Floor plaster should be given a heavy protective covering of Portland-cement mortar or concrete.

DAMP-PROOFING MOP AND BRUSH COATS

A common way of damp-proofing a cellar wall or floor is to mop coat the surface with hot coal-tar pitch or asphalt or to brush coat with a cold prepared bituminous or other water-repellant paint, as shown in Figure 18. Although this method has considerable water-

proofing value and is very useful for shedding seepage down the outside of a wall, it lacks the durability and effectiveness of a good felt membrane. In all instances the surface to be treated should be well prepared, as described on page 17. Paint coats require especially well-plugged, smooth, clean, dry surfaces. The last floor coat should generally be protected by a good layer of Portland-cement mortar or concrete. The last coat on the inner side of walls should be whitewashed, painted with Portland-cement grout, or given a Portland-cement plaster coat or other slightly granular finish.

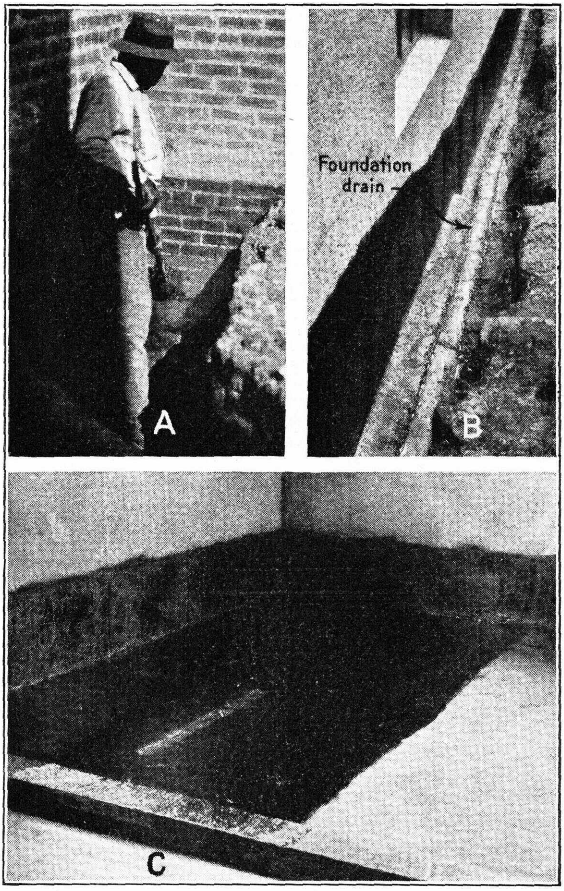

FIGURE 18.—Damp-proofing coatings: A, Applying a mop coat of hot bituminous compound to the outside of a cellar wall; B, wall below grading painted with four coats of thin water-gas tar and a seal coat of fluxed, refined coal tar; C, one panel of a basement floor and wall treated as is the wall in B, except that the light area has no seal coat

HOT COAL-TAR PITCH OR ASPHALT

The preparation and application of these materials have been explained on pages 17 to 21. Particular care should be taken in applying the priming coat to cover all spots and to fill all pores, hair cracks, or other small cavities. As soon as the primer sets, the surface should be given a heavy mop coat of the hot compound. When this coat is hard another mop coat should be applied and thoroughly swabbed so as to fill and cover any pinholes or thin spots in the first. Mopping on walls should proceed from the top downward and sideways.

PREPARED BITUMINOUS PAINT

Commercial bituminous paints are used for strictly damp-proofing purposes. The paint is applied cold with an ordinary paint brush and in at least two coats. The primer should be very thin and should be thoroughly brushed into all pores and minute cracks. It

is usually applied at the rate of 1 to 1½ gallons per 100 square feet, but the quantity will vary with the porosity and roughness of the surface. Within 24 hours the second coat is applied at the rate of 1 gallon per 100 square feet, giving a film approximately one sixty-fourth inch thick. Each additional coat of 1 gallon per 100 square feet will increase the thickness of the layer about one sixty-fourth inch. Earth back-filling may be done 24 hours after the application of the last coat, care being taken not to bruise or scar the paint.

WATER-GAS TAR AND COAL TAR

Water-gas tar and coal tar, obtainable at city gas works or from manufacturers of roofing materials, have proved effective for damp-proofing. Four coats of very thin water-gas tar, requiring about 2½ gallons per 100 square feet of masonry, are applied cold with a brush or spray. Sufficient time should be allowed between coats for each to be absorbed by the masonry. After the last coat is dry and when the air temperature is about 80° a seal coat of cold-fluxed refined coal tar is applied at the rate of ½ to 1 gallon per 100 square feet and thoroughly brushed in. Outdoor work generally dries in 24 to 48 hours. Indoor work may require more time. Examples of this treatment are shown in Figure 18.

CEMENT WASH

Walls may be somewhat damp-proofed by brushing on a wash, or grout, of Portland cement and water mixed to a thick, creamy consistency. Appearance and brightness are greatly improved by using white Portland cement.[1] All dust should first be removed and all cracks filled with mortar, then thoroughly dampened. The surface should be kept damp for several days after the wash is applied. Each coat should be thin and rubbed well in. Several may be needed. If greater protection is required, the mortar plaster previously described should be used.

IMPROVEMENT OF OLD CELLARS

Making old cellars water-tight and damp-proof is usually more difficult and costly than making new construction water-tight and damp-proof. Where it is desired to damp-proof or shed water down the back of a wall, outside work is more effective than inside work, but it necessitates the excavating of a work trench two or more feet wide. If outside work is decided upon the desirability of a foundation drain (see fig. 8) should not be overlooked.

It is sometimes inadvisable to dig a trench along the outside of a foundation because of the expense or the presence of trees or shrubbery. In such cases the tile, embedded in coarse gravel, is sometimes laid along the inside bottom of the foundation. The tile must lead to a drainage outlet and may be covered with the usual concrete floor. A drain thus located usually removes water pressure but is less effective than that shown in Figure 8 for protecting the outside and bottom of the wall and foundation.

Waterproofing is usually inside work. Damp-proofing is often applied inside because it is generally cheaper and causes less inconvenience than outside work. In general, work of this kind is done in

[1] Further information on cement washes, including coloring, is contained in Farmers' Bulletin 1772, Use of Concrete on the Farm.

a manner similar to that previously described for new construction of like character. The importance of properly preparing old surfaces should not be overlooked. All deep holes and depressions should be plugged with cement mortar, thus making it possible to apply plaster coats of fairly uniform thickness or to smooth the surface for brush or membrane work.

Cement plaster should never be applied to a dirty, dusty, or greasy surface. Paint, whitewash, and loose plaster should be removed. Cleaning is facilitated by the use of a wash composed of 1 part of muriatic acid and 5 to 10 parts of water. After a half hour the acid, dirt, and loose particles should be thoroughly washed off, preferably by flushing with a hose and scrubbing with a wire or stiff bristle brush. Smooth surfaces should be roughened by hacking with a peen hammer, old ax, or pick. Sometimes holes are punched in old floors to key the plaster securely. The joints of brick or stone masonry should be raked out to a depth of one-half inch. A groove is sometimes cut in seepage cracks and filled with well-tamped jute, oakum, or mortar, but it is generally advisable not to attempt plastering work when there is seepage from beneath or outside.

Furnaces, boilers, pipes, or woodwork which would break the continuity of plaster waterproofing coats should be temporarily removed. Where water may follow up the outside of a steel or iron post and the post can not conveniently be fitted with a tight flange or collar to be puddled into the floor, an expansion joint should be made around and against the post and should be filled with bituminous compound, as described on page 16.

CONDENSATION AND VENTILATION

It is unwise to spend money for waterproofing or damp-proofing work while there is possibility that the trouble is due to condensation of atmospheric moisture or to some more or less easily corrected minor cause. Leaky plumbing should be repaired, and close overhanging vines, shrubbery, or trees, productive of very deep shade, should be pruned or thinned out. Sunlight and free movement of air are wonderful agencies for removing dampness and wetness.

Water vapor from calm air is deposited or condensed on a cold surface under certain conditions of relative temperature and moisture content of the air. The surface appears to sweat. Sweating in cellars is more likely to give trouble in hot, sultry weather than in cool or cold weather at which times the atmosphere is usually comparatively dry. Sweating may be very profuse if the underground conditions are such as to make the walls or floor unduly cold or if the surface has been made glossy and impervious by the application of a damp-proofing paint. Under very unfavorable conditions the lower part of cellar walls may drip, and shallow pools of water may gather on the floor, a condition frequently attributed to seepage from outside.

Sweating is not easily controlled. The most feasible remedy is well-regulated ventilation. Since the atmosphere, when cool, is normally drier than when warm, ventilation should be regulated by adjusting window and bulkhead openings in accordance with the weather conditions. Generally, where sweating gives trouble, windows and bulkheads should be open night and day during fair

weather and when it is cooler outside than inside the cellar. During hot sticky weather or long rainy spells windows and bulkheads should be closed, because the outside air, at those times, is likely to be more moist than cellar air.

Screens should be provided to keep out mosquitoes, flies, and small animals Examples of cellar screening are shown in Figure 19.

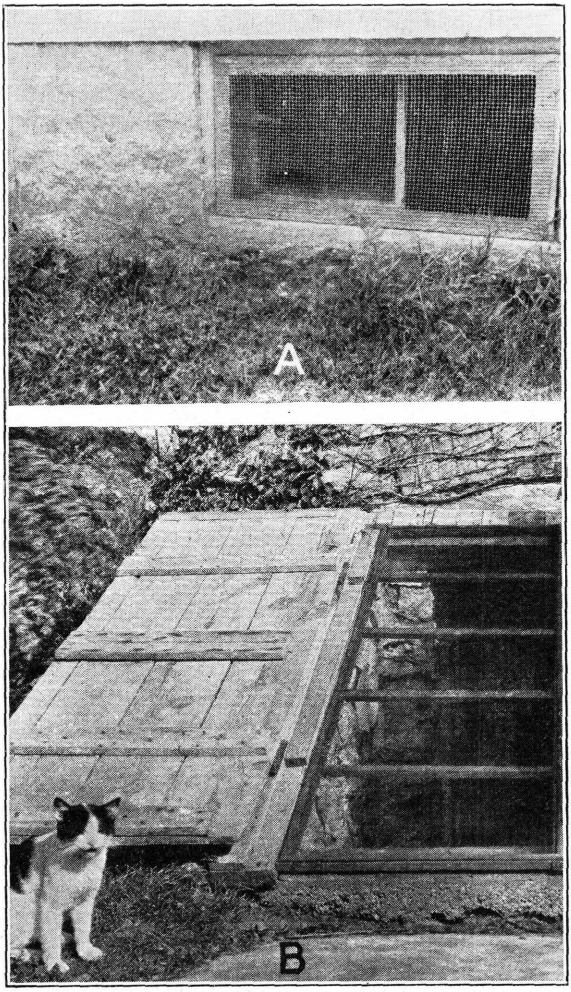

FIGURE 19.—Screened cellar openings. A, Screens having 4 meshes to an inch are common because they are strong and durable, but are too coarse to keep out flies; B, bulkhead nicely protected by a screen having 12 meshes to an inch

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